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## Public perception of climate engineering and carbon capture and storage in Germany: Survey evidence

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### Abstract

Climate engineering (CE) and carbon capture and storage are controversial options for addressing climate change. This study compares public perception in Germany of three specific measures: Solar radiation management (SRM) via stratospheric sulphate injection, large-scale afforestation, and carbon capture and storage sub-seabed (CCS-S). In a survey experiment we find that afforestation is most readily accepted as a measure for addressing climate change, followed by CCS-S and lastly SRM, which is widely rejected. Providing additional information decreases acceptance for all measures, but their ranking remains unchanged. The acceptance of all three measures is especially influenced by the perceived seriousness of climate change and by trust in institutions. Also, respondents dislike the measures more if they perceive them as a way of shirking responsibility for emissions or as an unconscionable manipulation of nature. Women react more negatively to information than men, while the level of education or the degree of intuitive vs. reflective decision-making does not influence the reaction to information.

## **Policy relevance**

Current projections suggest that the use of climate engineering (CE) technologies or carbon capture and storage (CCS) is necessary if global warming is to be kept well below 2°C. Our paper focuses on the perspective of the general public and thus supplements the dialogue between policymakers, interest groups, and scientists on how to address climate change. We show that in Germany public acceptance of potentially effective measures like SRM or CCS-S is low and decreases even more when additional information is provided. This implies that lack of public acceptance may turn out to be a bottleneck for future implementation. Ongoing research and development in connection with CCS-S and SRM requires continuous communication with, and involvement of, the public in order to obtain feedback and assess the public's reservations about the measures. The low level of acceptance also implies that emission reduction should remain a priority in climate policy.

## **Keywords**

climate engineering, solar radiation management, carbon capture and storage, climate change, public opinion, information

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# **Public perception of climate engineering and carbon capture and storage in Germany: Survey evidence**

## **1. Introduction**

The 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 21) has agreed on the goal of limiting global warming to less than 2°C above pre-industrial levels. However, even if there is a worldwide shift towards low-carbon economies, nearly all projections suggest that the 2°C target can only be achieved by large-scale climate engineering (CE) or carbon capture and storage (CCS) interventions (Anderson and Peters 2016; IPCC 2013; IPCC 2014). Both CE and CCS are currently controversial options for addressing climate change. At present, the costs, benefits, and risks of these new measures - especially CE - are not well understood, and their efficacy and side-effects remain uncertain (National Research Council Division on Earth and Life Studies et al. 2015a, 2015b; Rickels et al. 2011). Accordingly, further research on CE and CCS is necessary before they can become part of a portfolio for addressing climate change.

However, even limited field research on CE and CCS often meets with vociferous public protest (Deutscher Bundestag 2012; Dütschke et al. 2015; Federal Ministry for Economics and Technology 2011). This suggests that public acceptance will crucially determine the future of research on CE and CCS and hence the future of CE and CCS in general. However, public awareness of these measures is still low, and the impact of improved knowledge on public acceptance is unclear.

Our paper analyses public acceptance for three new measures designed to counteract climate change: two of them are CE measures – solar radiation management (SRM) and large-scale afforestation – the third is carbon capture and storage sub-seabed (CCS-S). In connection with these approaches, our study investigated the following research questions: (1) How does the public perceive them? (2) How does acceptance for the measures differ between uninformed and informed respondents? (3) How do personal characteristics influence perception of the measures?, and (4) Can personal characteristics explain differences in acceptance between uninformed and informed respondents? In an attempt to answer these questions, we conducted a large-scale online experiment involving more than 3,500 participants in Germany.

The aim of the first measure - SRM via the injection of sulphate aerosols into the stratosphere – is to block out some of the incoming sunlight and thus reduce global temperatures without removing carbon from the atmosphere. For simplicity, we will refer to this technology as SRM. The second

measure is large-scale afforestation, notably in extensive areas like the Sahara and the Australian Outback. Planting forests and replacing them once they are fully grown is a way of continuously removing CO<sub>2</sub> from the atmosphere. To prevent the CO<sub>2</sub> from re-entering the atmosphere, the logged trees can either be used as building material or buried. The third measure is carbon capture and storage sub-seabed (CCS-S). For CCS-S, CO<sub>2</sub> from industrial processes is captured before it enters the atmosphere and consigned to long-term storage under the seabed.

The three measures are heterogeneous with respect to levels of development, uncertainty about risks and benefits, people's familiarity with them, and location. This makes them interesting cases for comparison. Research on CE is still in its early stages. The uncertainty about side-effects is particularly high for SRM and large-scale afforestation. These side-effects would also occur globally. By contrast, CCS is comparatively well developed, test facilities exist, and the risks are mostly local. The three measures also differ in their potential. SRM has the highest expected potential in slowing global warming, followed by CCS and afforestation (Anderson and Peters 2016; Kreidenweis et al. 2016; Rickels et al. 2011). While CCS has already been discussed for several decades, most people are unfamiliar with the concept of SRM. The idea of planting trees in the Sahara is probably new to most people as well, but they have probably heard about reforestation. Finally, the measures intervene in different natural systems. CCS-S would be implemented underground, afforestation on land, and SRM in the stratosphere.

## **2. Literature review**

Comparative assessments of the public perception of the measures are still relatively scarce, and mostly focus on one measure only. Of the three approaches concerning us here, the perception of CCS has been most thoroughly researched so far (see Ashworth et al. 2010 and L'Orange Seigo et al. 2014 for an overview). Respondents from a broad range of countries are mostly either sceptical or undecided about CCS (e.g., Curry 2004; Duan 2010; Dütschke et al. 2015; Itaoka et al. 2012; Krause et al. 2014; Miller et al. 2008). Risk perception reduces acceptance, while benefit perception increases acceptance (Braun 2017; Duan 2010; Krause et al. 2014; Kraeusel and Most 2012; L'Orange et al. 2014; Schumann et al. 2014; Yang et al. 2016). The studies, however, display considerable variation, which is probably due to different national contexts, the specific storage location, regional factors and/or the information given to the respondents (Ashworth et al. 2010; Dowd et al. 2010; Pietzner et al. 2011; Terwel and Ter Mors 2015).

Generally, studies on SRM have reported low levels of acceptance (Mercer et al. 2011; Merk et al. 2015; see Bellamy et al. 2012 for an overview), while studies on afforestation suggest high levels of

acceptance (Curry et al. 2005; Lin et al. 2012). Some studies compared the attitudes to different measures and indicate that support for SRM is low compared to other CE measures (Bellamy et al. 2014; IPSOS Mori 2010; Wright et al. 2014). For example, a citizens' panel ranked afforestation more favourably than stratospheric sulphate injection (Bellamy 2016). A systematic comparison of the acceptance accorded to SRM, CCS-S, and afforestation has yet to be undertaken.

While a number of studies have investigated the effect of additional information on the acceptance of CCS, there are only very few for SRM and none for afforestation. With regard to SRM, Mercer et al. (2011) conclude that the provision of information does not have any substantial effect on acceptance. By contrast, Sütterlin and Siegrist (2016) have found that information lowers acceptance for SRM. In a similar vein, focus group studies have provided evidence that the more people learn about SRM, the more sceptical they become (Corner et al. 2012; Macnaghten and Szerszynski 2013).

For CCS, past studies have come up with conflicting results. On the one hand, several studies report a decrease in acceptance when respondents have received more information (Ha-Duong et al. 2009; Itaoka et al. 2009; 2012; L'Orange Seigo et al. 2011). Hobman and Ashworth (2013) suggest that respondents' acceptance of CCS remains unaffected by information about what it costs, but decreases as a result of information on emissions from energy generation. Terwel and Daamen (2012) found that informed respondents are more concerned about the safety risks of CCS. On the other hand, several studies have found an increase in acceptance after respondents received more information (Curry 2004; Curry et al. 2005; Curry et al. 2007; De Best-Waldhober et al. 2009; Itaoka et al. 2004; Shackley et al. 2005; Tokushige et al. 2007a; Tokushige et al. 2007b). Dowd et al. (2014) conclude that information reduces misconceptions about CCS. The authors also provide evidence that support for CCS is affected by the characteristics of CO<sub>2</sub> that are communicated to the respondents.

The influence of personal characteristics on acceptance for CE measures and CCS has been analysed before. For SRM, previous studies have found evidence that perception of the seriousness of climate change increases acceptance for this measure (Mercer et al. 2011; Merk et al. 2015; Pidgeon et al. 2012; Spence et al. 2010). Egoistic values, like the importance of social recognition, power, and wealth as guiding principles in life, generally increase acceptance for CE measures like SRM (Corner and Pidgeon 2014; Merk and Pönitzsch 2017), whereas altruistic values like the importance of equality, peace, and social justice have been found to either have no significant impact (Corner and Pidgeon 2014) or to reduce acceptance (Merk and Pönitzsch 2017). Egalitarian worldviews emphasising human benevolence and the need for altruistic cooperation have a detrimental effect on the acceptance of CE (Bellamy and Hulme 2011).

Ecological attitudes pertaining to the relationship between humanity and nature are an important factor influencing acceptance of large-scale interventions like SRM. For example, the attitude that humans will eventually learn to control nature increases acceptance for SRM, while a pronounced awareness of the fragility of natural equilibrium decreases acceptance (Merk and Pönitzsch 2017; Merk et al. 2015). Other studies have found that if a technology is perceived as natural, this will have an impact on the perception of risks and benefits (Siegrist et al. 2016; Slovic 2000); this has also been shown for CE measures (Corner et al. 2013; Corner and Pidgeon 2014; Macnaghten and Szerszynski 2013). For the perception of risks and acceptance, respondents' preferences for living in a safe environment and their willingness to take risks may also be important; for the latter, Merk et al. (2015) have reported a positive effect on acceptance for SRM.

Turning from these general attitudes to specific attitudes to the technologies in question, we again find an influence on acceptance. The conviction that humans should not manipulate nature in the way SRM does decreases acceptance (Merk et al. 2015). Carr (2014) argued that the perception of SRM as 'playing God' may have an impact on its acceptance, as religiosity is a determining factor in the support for other technologies like nanotechnology.

Alongside attitudes and beliefs, trust in institutions also affects acceptance. Trust has a positive influence on acceptance for both CCS and SRM (Merk et al. 2015; Terwel et al. 2009). Findings for other risky technologies suggest, however, that trust becomes less important, the more knowledgeable people are about a technology (Siegrist 2000). This would mean that people rely on institutions when their knowledge is scanty but rely on their own judgement once they know more.

Socio-demographic factors also potentially influence acceptance. Previous studies revealed that women tend to be more sceptical about CCS (Ha-Duong et al. 2009; Miller et al. 2007), while the results for CE measures are less clear (Corner and Pidgeon 2014; Merk et al. 2015; Pidgeon et al. 2012). The gender difference may be caused by framing and the amount of information available. In a basic information setting, L'Orange Seigo et al. (2011) found lower levels of acceptance in women than in men. Additional information on the monitoring of CCS had a negative influence only on men's acceptance, bringing it down to the same level as the women's.

Previous findings on the effect of education on acceptance are contradictory. Pidgeon et al. (2012) found a higher level of acceptance for SRM in well-educated people, while Merk et al. (2015) reported the reverse. Education can be interpreted as a proxy for whether decisions are made intuitively or not. To address this more directly, we included the cognitive reflection test (CRT) proposed by Frederick (2005). It distinguishes between intuitive and reflective decision-makers. Intuitive decision-makers are more risk-averse and more impatient than reflective decision-makers

(Frederick 2005; Oechssler et al. 2009).

In sum, our study contributes to the existing literature in various ways. First, we provide insights (for Germany) into the perception of three heterogeneous measures for dealing with climate change and compare them in a consistent framework. Second, we directly compare the influence of various factors on the acceptance accorded to the three measures. We include factors that have previously been found to be important in the context of risk perception and technology acceptance. We also consider new factors like the importance of living in a safe environment and reflective decision-making. Third, we analyse the effect of additional information on acceptance for the three measures. Fourth, we are the first to analyse the interaction between information and personal characteristics, values, and attitudes.

### **3. Data and survey design**

We conducted an online survey in August 2013. All respondents were recruited through a professional online panel and received a small monetary compensation for their participation. The survey consisted of six treatments: Respondents were randomly assigned to one of the three measures: SRM, afforestation, or CCS-S. For each measure, we implemented two information treatments. Respondents were randomly assigned to either the basic information (BI) or the full information (FI) treatment. The information treatments differed only with respect to the amount of information about the measure that respondents received. A total of 3,526 respondents completed the survey.<sup>1</sup>

The survey consisted of the following four parts: In the first part we elicited respondents' risk attitude (Dohmen et al. 2011). We enquired about the respondents' perception of the seriousness of climate change and their ecological values (New Ecological Paradigm Scale (NEP), Dunlap et al. 2000). Before providing respondents with information on one of the measures, we asked them about their awareness of the respective measure, i.e. whether they had heard about it before.

The second part contained the information treatment. Unlike previous studies using texts or pictures, we showed respondents a video with animated graphics. The animations provided a graphic explanation of the information and were supported by verbal explanations spoken by a professional radio presenter.<sup>2</sup> The video first provided respondents with information on anthropogenic climate change and its likely consequences. Then mitigation, adaptation, and either SRM, afforestation or CCS-S were introduced as possibilities for addressing climate change. Subsequently, the video gave a

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<sup>1</sup> Table A-1 reports all items used in our analysis.

<sup>2</sup> An English translation of the German script of the video is provided in appendix.



more detailed account of the respective measure. The video contained either basic information (BI treatment) or full information (FI treatment). In the BI treatment, respondents received background information, i.e. the mechanisms underlying the measure and its impact on climate change. In the FI treatment, respondents watched the BI information video and were then informed about the current state of research and the potential benefits and risks of the measure. Our aim was to present the information in a clear, scientifically accurate way. Accordingly, the information was based on peer-reviewed papers and scientific reports (e.g. Crutzen 2006; IPCC 2012; Ornstein et al. 2009; Royal Society 2009; UBA 2008). External experts checked the information for correctness and clarity.<sup>3</sup> In the third part we elicited the respondents' acceptance of the respective measure. The *acceptance* variable measures the level of acceptance for a specific measure, i.e. the level of (dis)agreement with its use.

We asked about attitudes towards the measure, such as 'humans should not interfere with nature in this way' or '[...] is the easy way out'. We also measured the degree of trust in the intentions of various actors or institutions to act in the interests of society and the environment. Subsequently, we elicited the respondents' egoistic, altruistic, and security values (Schwartz et al. 2012). After that, the respondents completed the cognitive reflection test (Frederik 2005). The fourth part contained questions on the respondents' socio-demographic characteristics.

#### 4. Analysis

The analysis was three-tiered. First, we used descriptive analysis to compare the respondents' perceptions of the different measures and to make an initial assessment of the different effects of information (basic or full) on acceptance.

Second, we used a regression framework to analyse how personal characteristics and information influence respondents' acceptance of the three measures. We estimated the following equation for each measure separately, using ordinary least squares regression:

$$(1) \quad \textit{acceptance}_i = \alpha + \beta \textit{info}_i + \gamma X_i + \varepsilon_i.$$

The dependent variable *acceptance* measures respondent *i*'s level of acceptance for a specific measure. Values ranged from 0 ('strongly disagree') to 3 ('strongly agree'). The treatment variable *info* had a value of 0 if the respondent participated in the BI treatment and 1 if she participated in the FI treatment. We considered the effect of various personal characteristics on acceptance. The vector *X* contained the following characteristics: risk attitude, perceived seriousness of climate change,

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<sup>3</sup> After the video, we asked respondents about the clarity of the presentation. Across all treatments more than 98% indicated that they had understood the video well or very well.

values, attitudes, trust, cognitive reflection, awareness, and socio-economic characteristics. The variables *ecological values (NEP)*, *egoistic values*, *altruistic values*, *security values*, and *trust* were standardised indices. The characteristic *awareness* was included as a dummy variable with a value of 0 if respondents had never heard about a measure before and 1 if respondents knew at least a little about it.<sup>4</sup>

Third, we investigated whether respondents react differently to information depending on their personal characteristics. We estimated equation (II), which encompassed all the above variables and the interaction term ( $x_i \times info_i$ ). The coefficient,  $\delta$ , indicated the change in the information effect with a one-unit change in personal characteristic  $x_i$ .

$$(II) \text{ acceptance}_i = \alpha + \beta info_i + \gamma X_i + \delta(x_i \times info_i) + \varepsilon_i.$$

## 5. Results

### 5.1 Descriptive results

SRM was by far the least well-known measure among our respondents, followed by CCS-S and afforestation. Self-reported awareness differed significantly and strongly between SRM, CCS-S, and afforestation (Wilcoxon rank sum tests  $p \leq 0.001$ ). Less than a quarter of the respondents had heard at least a little about SRM (22%), whereas the majority of the respondents had at least heard a little about CCS-S (52%). For afforestation, we found an even higher awareness: 60% stated that they had heard at least a little about afforestation before.

Figure 1 shows respondents' acceptance of SRM, CCS-S, and afforestation in the BI treatment and FI treatment.

SRM had the lowest acceptance scores. Respondents were divided on CCS-S, while afforestation was widely accepted. Figure 1 shows respondents' answers to the question whether they would accept the use of SRM, CCS-S, or afforestation to counteract climate change in the BI and the FI treatments.

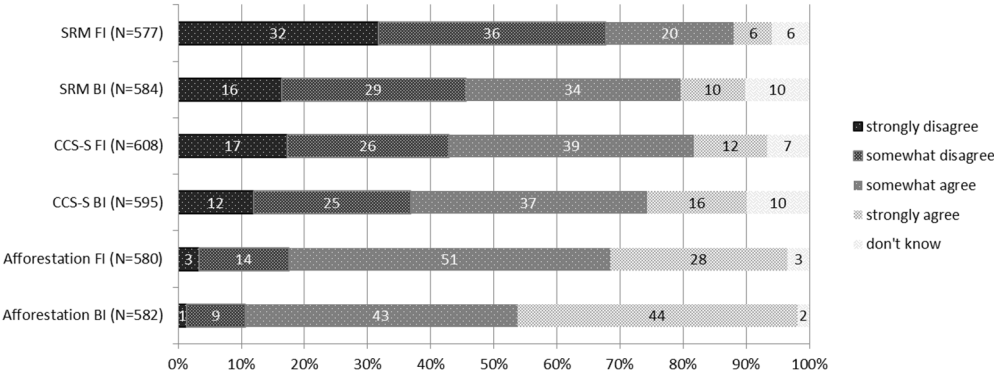
Additional information reduced acceptance for all the measures, but it did not change their ranking. Acceptance for all technologies was significantly lower in the full information (FI) treatment than in the basic information (BI) treatment (Wilcoxon rank sum tests, SRM  $p < 0.001$ , CCS-S  $p = 0.007$ , afforestation  $p < 0.001$ ). The effect of information was strongest for SRM (BI: 44% of the respondents agreed somewhat or strongly with the use of SRM versus FI: 26% who agreed somewhat or strongly with the use of SRM), and it remained the measure accorded by far the lowest degree of acceptance. The decrease in acceptance was weakest for CCS-S. Fifty-three percent of the respondents who were

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<sup>4</sup> Summary statistics can be found in table A-2 in the appendix.

given basic information only agreed somewhat or strongly that CCS-S should be used to counteract climate change, compared to 51% who agreed somewhat or strongly with the use of CCS-S in the FI treatment. For afforestation, the proportion of respondents who agreed with the use of afforestation to counteract climate change was 8 percentage points lower in the FI treatment than in the BI treatment (FI: 79% agreed with the use of afforestation versus BI: 87% agreed with the use of afforestation). However, acceptance remained very high.

**Figure 1:** Acceptance of SRM, CCS-S and afforestation in the FI and BI treatments



Note: The survey asked the following question: “We should use [...] to counteract climate change.” Own presentation

**5.2 Regression results**

For each measure, Table 1 shows the results for equation (I) on the factors influencing acceptance and the role of information. Table 2 provides the results of equation (II) on interaction effects. In columns (2) to (6) of Table 2, we have sequentially added terms for interaction between *info* and one personal characteristic. We ran regressions including terms for interaction with all personal characteristics, but Table 2 only reports coefficient estimates for interaction terms that are statistically significant for at least one measure.<sup>5</sup>

**Factors influencing acceptance**

The results in Table 1 confirm that the treatment variable *info* had a significantly negative effect on acceptance for all the measures. Acceptance was generally lower in the FI treatment than in the BI treatment. SRM displayed the strongest effect. Here, acceptance decreased by 0.29 points between the BI and FI treatments. Acceptance for CCS-S was 0.17 points lower in the FI treatment than in the BI treatment. The results were similar for afforestation. Acceptance decreased by 0.18 points

<sup>5</sup> Tables A-3 to A-5 in the Appendix show all regressions.

between the BI and FI treatments. In short, for all three measures we found systematic evidence that information reduces acceptance.

**Table 1:** OLS regression results equation (I)

Acceptance	SRM	CCS-S	Afforestation
info	-0.29*** (0.05)	-0.17*** (0.05)	-0.18*** (0.04)
awareness	-0.12** (0.06)	-0.02 (0.05)	0.04 (0.04)
risk attitude	0.05*** (0.01)	0.03** (0.01)	0.02 (0.01)
seriousness of climate change	0.13*** (0.04)	0.14*** (0.04)	0.13*** (0.04)
<i>Values</i>			
ecological	-0.00 (0.05)	-0.09* (0.05)	0.11** (0.04)
altruistic	-0.03 (0.04)	0.01 (0.04)	-0.02 (0.03)
egoistic	0.11*** (0.04)	0.04 (0.04)	0.09*** (0.03)
security	0.06 (0.04)	0.11*** (0.04)	0.07** (0.03)
<i>Attitudes</i>			
is easy way out	-0.14*** (0.04)	-0.14*** (0.04)	-0.11*** (0.03)
not manipulate this way	-0.43*** (0.04)	-0.39*** (0.04)	-0.26*** (0.03)
<i>Other Factors</i>			
trust	0.31*** (0.04)	0.32*** (0.04)	0.24*** (0.04)
cognitive reflection	-0.09*** (0.02)	-0.09*** (0.02)	-0.04* (0.02)
<i>Socio-demographics</i>			
religiousness	0.07*** (0.02)	0.00 (0.02)	0.05** (0.02)
female	0.11** (0.05)	0.08 (0.05)	-0.03 (0.05)
high education	-0.13** (0.05)	-0.10* (0.05)	-0.06 (0.05)
age	0.00 (0.00)	0.00 (0.00)	0.00* (0.00)
region	-0.04 (0.06)	-0.21*** (0.07)	-0.03 (0.06)
constant	2.02*** (0.18)	2.22*** (0.18)	2.23*** (0.16)
Observations	846	897	898
Adjusted $R^2$	0.4775	0.4412	0.3202

Standard errors in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Our regression results also show that, for SRM, prior awareness of the technology significantly lowered acceptance. For CCS-S and afforestation we did not find any significant effect of awareness on acceptance. We also found that respondents' risk attitude had a significant effect on the acceptance of SRM and CCS-S. Risk-seeking respondents were more likely to accept the use of a measure than risk-averse respondents. Perception of the seriousness of climate change also affected acceptance. Respondents who perceived climate change as a serious problem were more generous in their acceptance of all the measures.

Values also influence acceptance. For SRM, we found that more egoistic respondents tended to accept the measure more readily than less egoistic respondents. For CCS-S, security-seeking respondents show a statistically significant higher acceptance. For afforestation, respondents with higher scores for ecological values and more egoistic respondents displayed significantly higher acceptance. We also found that attitudes significantly affected the acceptance of all three measures. Respondents who either thought that a given measure was the easy way out or that humans should not manipulate nature in this way displayed significantly lower acceptance. Trust in institutions had a significantly positive effect. Cognitive reflection had a significantly negative effect on acceptance for all three measures.

We also found that socio-demographic variables influence acceptance. For both SRM and afforestation, more religious respondents displayed significantly higher acceptance. For SRM, women showed a higher degree of acceptance than men. By contrast, we did not find any significant gender differences between acceptance for CCS-S and afforestation. We also analysed whether the level of acceptance varied between the different states in Germany. The acceptance of CCS was 0.21 points lower in Schleswig-Holstein and Lower Saxony compared to the rest of Germany. The perception of respondents from Schleswig-Holstein and Lower Saxony differs from those in other parts of Germany most likely because these states have already experienced vehement public protests against CCS in the past. For SRM and afforestation, we did not find any significant regional differences.

### ***Interaction terms***

We found evidence suggesting that individuals' reactions to information depended to a certain extent on their personal characteristics (table 2).

For SRM and afforestation, we found that the negative effect of information on acceptance was larger for women than for men; women reacted much more strongly to information than men. For SRM, information for men decreased acceptance by 0.20 points (SRM-2: *info*), information for women by 0.41 points (sum of *info* and *female \* info*). The decline in acceptance was 0.21 points

higher for women than for men, and this difference is statistically significant at the 5% level. With this decline in women's acceptance by 0.21 points the gender difference vanished and women's acceptance levelled with that of the men in the FI treatment. For afforestation, men's acceptance was not significantly different between the FI and BI treatments (Aff-2: *info*). By contrast, women's acceptance was significantly lower in the FI than in the BI treatment (sum of *info* and *female \* info*). Hence, for afforestation the negative overall effect of information was mostly due to the negative effect it had on women.

For SRM, we also found that the effect of information depended on respondents' *risk attitudes* (SRM-3: *risk attitude \* info*). Risk-seeking respondents reacted less negatively to information than risk-averse respondents. The effect of information increased by 0.05 points for every one-unit increase in the risk-seeking variable. This implies that the risk-averse respondents attached greater significance to the risks of SRM once they had been informed about its risks and benefits.

Another factor determining the effect of information on SRM acceptance (SRM-4) was the perceived *seriousness of climate change*. Respondents who perceived climate change as a serious problem displayed higher acceptance for SRM (*seriousness of climate change*), but they also reacted more negatively to information than respondents who did not perceive climate change as a serious problem. A one-point increase in the perceived seriousness of climate change reduced the effect of information by 0.14 points (SRM-4: *seriousness of climate change \* info*). A likely explanation is that respondents who considered climate change to be a serious problem were more likely to consider ways of addressing climate change in the first place (SRM-4: *seriousness of climate change*). Accordingly, additional information was only relevant for those respondents. By contrast, respondents who did not think that climate change was serious did not consider the use of SRM, irrespective of the amount of information they received.

We also found that the negative effect of information on the acceptance of SRM was less pronounced in more *egoistic* respondents (SRM-6). They may have perceived additional information on the benefits more strongly and/or the additional information on the risks and side-effects less strongly than less egoistic respondents. They may therefore have reacted less negatively to the additional information. Finally, we found for CCS-S that more altruistic respondents reacted more negatively to information than less altruistic respondents (CCS-S-5).

Interestingly, neither education nor cognitive reflection had any bearing on the effect of additional information on acceptance. This suggests that understanding and interpreting the information did not depend on cognitive decision-making styles or the level of education.

**Table 2:** OLS regression results equation (II)

Acceptance	SRM					CCS-S					Afforestation				
	(SRM-2)	(SRM-3)	(SRM-4)	(SRM-5)	(SRM-6)	(CCS-S-2)	(CCS-S-3)	(CCS-S-4)	(CCS-S-5)	(CCS-S-6)	(Aff-2)	(Aff-3)	(Aff-4)	(Aff-5)	(Aff-6)
info	-0.20*** (0.06)	-0.55*** (0.12)	0.20 (0.24)	-0.29*** (0.05)	-0.30*** (0.05)	-0.13** (0.07)	-0.08 (0.14)	0.14 (0.27)	-0.16*** (0.05)	-0.17*** (0.05)	-0.07 (0.06)	-0.23** (0.11)	0.20 (0.27)	-0.18*** (0.04)	-0.18*** (0.04)
female	0.22*** (0.07)	0.11** (0.05)	0.10** (0.05)	0.11** (0.05)	0.11** (0.05)	0.12 (0.07)	0.08 (0.05)	0.08 (0.05)	0.08 (0.05)	0.08 (0.05)	0.09 (0.06)	-0.03 (0.05)	-0.03 (0.05)	-0.03 (0.05)	-0.03 (0.05)
risk attitude	0.05*** (0.01)	0.02 (0.01)	0.05*** (0.01)	0.05*** (0.01)	0.05*** (0.01)	0.03** (0.01)	0.04* (0.02)	0.03** (0.01)	0.03** (0.01)	0.03** (0.01)	0.01 (0.01)	0.01 (0.01)	0.02 (0.01)	0.02 (0.01)	0.01 (0.01)
seriousness of climate change	0.13*** (0.04)	0.13*** (0.04)	0.21*** (0.05)	0.13*** (0.04)	0.13*** (0.04)	0.14*** (0.04)	0.14*** (0.04)	0.18*** (0.06)	0.14*** (0.04)	0.14*** (0.04)	0.13*** (0.04)	0.13*** (0.04)	0.18*** (0.05)	0.13*** (0.04)	0.13*** (0.04)
altruistic	-0.04 (0.04)	-0.03 (0.04)	-0.04 (0.04)	-0.03 (0.05)	-0.03 (0.04)	0.01 (0.04)	0.01 (0.04)	0.01 (0.04)	0.07 (0.05)	0.01 (0.04)	-0.02 (0.03)	-0.02 (0.03)	-0.02 (0.03)	0.01 (0.04)	-0.02 (0.03)
egoistic	0.11*** (0.04)	0.11*** (0.04)	0.11*** (0.04)	0.11*** (0.04)	0.04 (0.05)	0.05 (0.04)	0.04 (0.04)	0.04 (0.04)	0.05 (0.04)	0.05 (0.06)	0.09*** (0.03)	0.09*** (0.03)	0.09*** (0.03)	0.09*** (0.03)	0.07* (0.04)
female * info	-0.21** (0.09)					-0.08 (0.09)					-0.25*** (0.08)				
risk attitude * info		0.05** (0.02)					-0.02 (0.02)					0.01 (0.02)			
seriousness of climate change * info			-0.14** (0.07)					-0.09 (0.07)					-0.11 (0.07)		
altruistic * info				0.00 (0.07)					-0.11* (0.07)					-0.06 (0.06)	
egoistic * info					0.13** (0.07)					-0.01 (0.07)					0.04 (0.06)
Other controls	All	All	All	All	All	All	All	All	All	All	All	All	All	All	All
Observations	846	846	846	846	846	897	897	897	897	897	898	898	898	898	898
Adjusted R <sup>2</sup>	0.4801	0.4802	0.4801	0.4769	0.4798	0.4410	0.4409	0.4417	0.4427	0.4406	0.3260	0.3196	0.3221	0.3202	0.3199

Standard errors in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

## 6. Discussion and conclusion

In our survey experiment we compared the acceptance in Germany of three new measures for tackling climate change: SRM, CCS-S, and afforestation. We tested for the influence on acceptance of providing basic information only vs. providing extensive information. Our analysis was designed to establish the factors that influence acceptance and the effect of information. Our main findings are that SRM via stratospheric aerosol injection is widely rejected, while large-scale afforestation is widely accepted. Our respondents were divided about CCS-S. Providing additional information decreased acceptance for all measures, but their ranking remained unchanged. Women reacted more negatively to information than men, while the level of education or the degree of intuitive vs. reflective decision-making did not influence the reaction to information. Overall, acceptance of all three measures was especially influenced by the perceived seriousness of climate change and trust in institutions. Furthermore, people disliked the measures more when they perceived them as an excuse for shirking emission responsibility or as an unconscionable manipulation of nature.

This study represents a comparative analysis of the acceptance of measures that are heterogeneous with respect to their level of development, uncertainty about risks and benefits, people's familiarity with them, and location. Acceptance was lowest for SRM via stratospheric sulphate injection, which is also the least widely known of the three measures. This confirms previous findings which indicated that SRM is least favoured among CE (Bellamy 2016; Wright et al. 2014). About half of the respondents had already heard about CCS-S, so the effect of information was lowest, but additional information lowered acceptance even more. In addition, lower levels of acceptance in regions where there had been protests against demonstration plants indicate that more information and higher familiarity with the measures lower acceptance (Braun 2017). This furthermore confirms previous findings from studies on SRM (Corner et al. 2012; Macnaghten and Szerszynski 2013; Sütterlin and Siegrist 2016). The result suggests that SRM may run into even greater acceptance problems in the future when people learn more about it.

Our results also confirm previous findings on the positive impact of trust in institutions and climate change perception (e.g. Mercer et al. 2011; Merk et al. 2015; Pidgeon et al. 2012; Spence et al. 2010). Unlike Pidgeon et al. (2012), we found that education had a negative effect on SRM acceptance. This effect remained when we included the degree of reflective decision-making, which also had a negative effect on acceptance for all three measures. Previous results on gender differences in acceptance were inconclusive (Corner and Pidgeon 2014; Pidgeon et al. 2012). We found that in the basic information treatment, women displayed higher acceptance of SRM than men. However, this gender difference vanished in the full information treatment, where women's acceptance was lower,



approximating that of men. Thus, our results contradict previous findings for CCS (L'Orange Seigo et al. 2011).

Our results imply that for CE and CCS, public perception is an important bottleneck for future implementation. Afforestation was the most readily accepted of the three measures we analysed, but it is also considered to be least effective in addressing climate change (Rickels et al. 2011). In contrast, SRM is considered to be very effective, but people are clearly extremely averse to the idea of SRM. Many people even reject the idea of SRM field research (Merk et al. 2015) and in the past, CE and CCS field research has already led to protests in Germany (Deutscher Bundestag 2012; Dütschke 2010; Dütschke et al. 2015; Federal Ministry for Economics and Technology 2011). However, research on the risks, benefits, and technical feasibility of these measures will be necessary before deployment can even be contemplated (Rayner et al. 2009; Rickels et al. 2011). Further progress with research and development in connection with CCS-S and SRM requires continuous communication with, and involvement of, the public to obtain feedback and assess the public's reservations about the measures (Corner et al. 2012; Pidgeon et al. 2013; Rayner et al. 2009).

In terms of climate policy, our results indicate that reducing the level of CO<sub>2</sub> emissions, e.g. by switching from fossil to renewable fuels or reducing energy consumption, should remain the number-one priority in tackling climate change. Current projections in which temperature increases remain below 2°C rely heavily on negative emissions from bioenergy and carbon capture and storage (BECCS) (Anderson and Peters 2016; IPCC 2014; IEA 2015). But if low public acceptance for CCS prevents its use in the future, current investment in emission reduction may be too low. For CCS this is already an issue, but for SRM and other CE measures this may become relevant in the future as well. Discussion about them has gained substantial momentum in recent years and has been fuelled further by COP 21 tightening the 2°C goal to keep global temperatures “well below” 2°C.

Our study provides a snapshot of public acceptance obtained in a controlled setting at a time when extensive media coverage and lively public discourse, especially on SRM and large-scale afforestation, are still conspicuous by their absence. Accordingly, our results must be interpreted in the light of the information we provided in the video. The respondents' familiarity with the measures was low. Therefore, the video was their main source of information and its framing may have influenced responses (Sütterlin and Siegrist 2016; Bellamy et al. 2012; Corner et al. 2013; Corner and Pidgeon 2014; Dowd et al. 2014). For example, comparing SRM to a volcanic eruption, as we did, could increase the perceived naturalness of SRM and thus increase acceptance (Bellamy et al. 2014; Corner and Pidgeon 2014; Macnaghten and Szerszynski 2013; Pidgeon et al. 2012). Aware of the importance of framing effects, we opted for neutral, scientific framing in the video and were careful to refrain

from asking 'leading' questions and to avoid any kind of bias. However, future discourse on CE and CCS-S will be shaped by various actors like the media, NGOs, or the industry, all with their own interests and agendas. Moreover, it must be noted that public perception might differ both between countries and within countries over time (Braun et al. 2017; Pietzner et al. 2011). Therefore, our results for Germany do not necessarily apply to other countries. We leave it to future cross-country studies to examine these differences in public perception.

Overall the results of this study show that the provision of additional information strongly affects public perception of CE and CCS in Germany. Given the scepticism that we find, it seems critically important to understand the drivers of public perception of CE and CCS. In case the public considers the use of CE and CCS as unacceptable for mitigating climate change, significant societal changes associated with deep emission reductions and adaption measures may be necessary.

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## Appendix to “Public perception of climate engineering and carbon capture and storage in Germany: survey evidence”

**Table A-1:** Survey items

<i>Question and items</i>	<i>response scale</i>
<b>Risk attitude</b>	
Are you generally a person who is fully prepared to take risks or do you try to avoid taking risks?	risk-averse (0) - risk-seeking (10)
<b>Seriousness of climate change</b>	
Global warming is a serious problem.	strongly disagree (0) - strongly agree (3)
<b>Ecological values (Cronbach’s <math>\alpha = 0.5756</math>)</b>	
The Earth is like a spaceship with very limited room and resources.	strongly disagree (0) - strongly agree (3)
Humans were meant to rule over the rest of nature.	
The balance of nature is very delicate and easily upset.	
Humans will eventually learn enough about how nature works to be able to control it.	
If things continue on their present course, we will soon experience a major ecological catastrophe.	
<b>Altruistic values (Cronbach’s <math>\alpha = 0.7224</math>)</b>	
She thinks it is important for everyone to have equal opportunities in life.	very dissimilar (0) - very similar (3)
She works to promote peace among diverse groups.	
Protecting society’s weak and vulnerable members is important to her.	
Caring for the well-being of people she is close to is important to her.	
<b>Egoistic values (Cronbach’s <math>\alpha = 0.7724</math>)</b>	
She wants people to do what she says.	very dissimilar (0) - very similar (3)
Being wealthy is important to her.	
It is important for her to be the one who tells the others what to do.	
It is important for her to be the most influential person in any group.	
<b>Security values (Cronbach’s <math>\alpha = 0.7114</math>)</b>	
Her personal security is extremely important to her.	very dissimilar (0) - very similar (3)
She avoids anything that might endanger her safety.	
It is important for her to live in secure surroundings.	
Order and stability in society are important to her.	
<b>Awareness</b>	
Have you ever heard about [...] before or have you never heard about it before?	No, I have never heard about it. Yes, I have heard a little about it. Yes, I have heard a lot about it.
<b>Acceptance</b>	
We should use [...] to counteract climate change.	strongly disagree (0) - strongly agree (3)
<b>Attitudes</b>	
[...] is the easy way out.	strongly disagree (0) - strongly agree (3)
Humans should not be manipulating nature in this way.	

<b>Questions and items (continued)</b>	<b>response scale</b>
<p><b>Trust (Cronbach's <math>\alpha = 0.7942</math>)</b></p> <p>How strongly do you feel that these groups will act in the interests of society and the environment?</p> <ul style="list-style-type: none"> <li>Federal government</li> <li>Companies involved in [...] projects</li> <li>Environmental organisations</li> <li>Media</li> <li>Researchers studying at publicly funded research institutes</li> <li>United Nations</li> <li>European Union</li> </ul>	do not trust at all (0) - trust completely (3)
<p><b>Cognitive reflection</b></p> <p>Together, a bat and a ball cost \$1.10. The bat costs \$1.00 more than the ball. How much does the ball cost?</p> <p>If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?</p> <p>In a lake there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?</p>	any number
<p><b>Religiousness</b></p> <p>How religious are you?</p>	not religious at all (0) - very religious (3)
<p><b>Education</b></p> <p>What is your highest degree or school-leaving certificate?</p>	7 degrees
<p><b>Region</b></p> <p>Which Federal State do you live in?</p>	16 states

**Table A-2:** Summary statistics

<i>Variables</i>	<i>Domain</i>	<i>SRM</i>		<i>CCS-S</i>		<i>Afforestation</i>	
		<i>mean</i>	<i>standard deviation</i>	<i>mean</i>	<i>standard deviation</i>	<i>mean</i>	<i>standard deviation</i>
acceptance	0 - 3	1.21	0.93	1.56	0.93	1.20	0.74
awareness	0 (have never heard); 1 (have heard at least a little bit)	0.22		0.52		0.60	
risk attitude	0 - 10	5.39	2.26	5.36	2.20	5.37	2.31
seriousness of climate change	0 - 3	2.51	0.71	2.51	0.71	2.51	0.70
ecological values	standardised index	-0.029	0.61	0.017	0.61	0.001	0.61
altruistic values	standardised index	-0.023	0.74	0.039	0.74	-0.026	0.74
egoistic values	standardised index	0.001	0.77	-0.024	0.74	0.032	0.80
security values	standardised index	-0.002	0.74	0.019	0.73	-0.025	0.73
Attitudes - easy way out	0 - 3	2.17	0.84	2.09	0.85	1.69	0.85
Attitudes - not manipulate in this way	0 - 3	2.19	0.85	2.02	0.88	1.21	0.85
trust	standardised index	-0.021	0.67	-0.059	0.67	0.095	0.66
cognitive reflection test	0 - 3	0.98	1.03	1.06	1.03	1.05	1.03
religiousness	0 - 3	1.01	0.94	1.04	0.97	1.02	0.96
female	0 (Male); 1 (Female)	49%		50%		49%	
high education	0 (other); 1 (A level)	36%		35%		36%	
age	18 - 87	47	15.33	48	15.33	47	15.15
region	0 (other); 1 (Schleswig-Holstein or Lower Saxony)	14%		12%		13%	
N		1161		1203		1162	

**Table A-3: OLS regression results for SRM**

Acceptance of SRM	(SRM-1)	(SRM-2)	(SRM-3)	(SRM-4)	(SRM-5)	(SRM-6)
info	-0.29*** (0.05)	-0.20*** (0.06)	-0.55*** (0.12)	0.20 (0.24)	-0.29*** (0.05)	-0.30*** (0.05)
awareness	-0.12** (0.06)	-0.11** (0.06)	-0.12** (0.06)	-0.12** (0.06)	-0.12** (0.06)	-0.11** (0.06)
risk attitude	0.05*** (0.01)	0.05*** (0.01)	0.02 (0.01)	0.05*** (0.01)	0.05*** (0.01)	0.05*** (0.01)
seriousness of climate change	0.13*** (0.04)	0.13*** (0.04)	0.13*** (0.04)	0.21*** (0.05)	0.13*** (0.04)	0.13*** (0.04)
<i>Values</i>						
ecological	-0.00 (0.05)	-0.01 (0.05)	0.00 (0.05)	-0.01 (0.05)	-0.00 (0.05)	-0.00 (0.05)
altruistic	-0.03 (0.04)	-0.04 (0.04)	-0.03 (0.04)	-0.04 (0.04)	-0.03 (0.05)	-0.03 (0.04)
egoistic	0.11*** (0.04)	0.11*** (0.04)	0.11*** (0.04)	0.11*** (0.04)	0.11*** (0.04)	0.04 (0.05)
security	0.06 (0.04)	0.06 (0.04)	0.06 (0.04)	0.06 (0.04)	0.06 (0.04)	0.06 (0.04)
<i>Attitudes</i>						
is easy way out	-0.14*** (0.04)	-0.14*** (0.04)	-0.14*** (0.04)	-0.14*** (0.04)	-0.15*** (0.04)	-0.14*** (0.04)
not manipulate this way	-0.43*** (0.04)	-0.43*** (0.04)	-0.43*** (0.04)	-0.42*** (0.04)	-0.43*** (0.04)	-0.43*** (0.04)
<i>Other Factors</i>						
trust	0.31*** (0.04)	0.31*** (0.04)	0.31*** (0.04)	0.31*** (0.04)	0.31*** (0.04)	0.31*** (0.04)
cognitive reflection	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)
<i>Socio-demographics</i>						
religiousness	0.07*** (0.02)	0.07*** (0.02)	0.07*** (0.02)	0.07*** (0.02)	0.07*** (0.02)	0.07*** (0.02)
female	0.11** (0.05)	0.22*** (0.07)	0.11** (0.05)	0.10** (0.05)	0.11** (0.05)	0.11** (0.05)
high education	-0.13** (0.05)	-0.13** (0.05)	-0.14*** (0.05)	-0.13** (0.05)	-0.13** (0.05)	-0.14*** (0.05)
age	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
region	-0.04 (0.06)	-0.05 (0.06)	-0.05 (0.06)	-0.04 (0.06)	-0.04 (0.06)	-0.04 (0.06)
<i>Interaction Terms</i>						
female * info		-0.21** (0.09)				
risk attitude * info			0.05** (0.02)			
seriousness of climate change * info				-0.14** (0.07)		
altruistic * info					0.00 (0.07)	
egoistic* info						0.13** (0.07)
constant	2.02*** (0.18)	1.95*** (0.18)	2.15*** (0.19)	1.82*** (0.21)	2.02*** (0.18)	2.00*** (0.18)
Observations	846	846	846	846	846	846
Adjusted R <sup>2</sup>	0.4775	0.4801	0.4802	0.4801	0.4769	0.4798

Standard errors in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A-3: OLS regression of SRM acceptance. Note: Acceptance is measured on a scale of 0 (strongly disagree) to 3 (strongly agree). All other variables are also measured on scales of 0 to 3. Exceptions are dummy variables (info, awareness, female, high education, region), risk attitude (scale is from 0 to 10), and age. Variables for values and trust are standardised indices.

**Table A-4:** OLS regression results for CCS-S

Acceptance of CCS-S	(CCS-1)	(CCS-2)	(CCS-3)	(CCS-4)	(CCS-5)	(CCS-6)
info	-0.17*** (0.05)	-0.13** (0.07)	-0.08 (0.14)	0.14 (0.27)	-0.16*** (0.05)	-0.17*** (0.05)
awareness	-0.02 (0.05)	-0.02 (0.05)	-0.02 (0.05)	-0.02 (0.05)	-0.02 (0.05)	-0.02 (0.05)
risk attitude	0.03** (0.01)	0.03** (0.01)	0.04* (0.02)	0.03** (0.01)	0.03** (0.01)	0.03** (0.01)
seriousness of climate change	0.14*** (0.04)	0.14*** (0.04)	0.14*** (0.04)	0.18*** (0.06)	0.14*** (0.04)	0.14*** (0.04)
<i>Values</i>						
ecological	-0.09* (0.05)	-0.09* (0.05)	-0.09* (0.05)	-0.09** (0.05)	-0.10** (0.05)	-0.09* (0.05)
altruistic	0.01 (0.04)	0.01 (0.04)	0.01 (0.04)	0.01 (0.04)	0.07 (0.05)	0.01 (0.04)
egoistic	0.04 (0.04)	0.05 (0.04)	0.04 (0.04)	0.04 (0.04)	0.05 (0.04)	0.05 (0.06)
security	0.11*** (0.04)	0.11*** (0.04)	0.11*** (0.04)	0.10*** (0.04)	0.10*** (0.04)	0.11*** (0.04)
<i>Attitudes</i>						
is easy way out	-0.14*** (0.04)	-0.14*** (0.04)	-0.14*** (0.04)	-0.15*** (0.04)	-0.15*** (0.04)	-0.14*** (0.04)
not manipulate this way	-0.39*** (0.04)	-0.39*** (0.04)	-0.39*** (0.04)	-0.39*** (0.04)	-0.39*** (0.04)	-0.39*** (0.04)
<i>Other Factors</i>						
trust	0.32*** (0.04)	0.32*** (0.04)	0.33*** (0.04)	0.33*** (0.04)	0.32*** (0.04)	0.32*** (0.04)
cognitive reflection	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)	-0.09*** (0.02)
<i>Socio-demographics</i>						
religiousness	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)	0.00 (0.02)
female	0.08 (0.05)	0.12 (0.07)	0.08 (0.05)	0.08 (0.05)	0.08 (0.05)	0.08 (0.05)
high education	-0.10* (0.05)	-0.10* (0.05)	-0.10* (0.05)	-0.10* (0.05)	-0.10* (0.05)	-0.10* (0.05)
age	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
region	-0.21*** (0.07)	-0.21*** (0.07)	-0.21*** (0.07)	-0.21*** (0.07)	-0.21*** (0.07)	-0.21*** (0.07)
<i>Interaction Terms</i>						
female * info		-0.08 (0.09)				
risk attitude * info			-0.02 (0.02)			
seriousness of climate change * info				-0.09 (0.07)		
altruistic * info					-0.11* (0.07)	
egoistic* info						-0.01 (0.07)
Constant	2.22*** (0.18)	2.20*** (0.18)	2.18*** (0.19)	2.09*** (0.22)	2.21*** (0.18)	2.22*** (0.18)
Observations	897	897	897	897	897	897
Adjusted R <sup>2</sup>	0.4412	0.4410	0.4409	0.4417	0.4427	0.4406

Standard errors in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A-4: OLS regression of CCS-S acceptance. Note: Acceptance is measured on a scale of 0 (strongly disagree) to 3 (strongly agree). All other variables are also measured on scales of 0 to 3. Exceptions are dummy variables (info, awareness, female, high education, region), risk attitude (scale is from 0 to 10), and age. Variables for values and trust are standardised indices.

**Table A-5: OLS regression results for afforestation**

Acceptance of afforestation	(Aff-1)	(Aff-2)	(Aff-3)	(Aff-4)	(Aff-5)	(Aff-6)
info	-0.18*** (0.04)	-0.07 (0.06)	-0.23** (0.11)	0.20 (0.27)	-0.18*** (0.04)	-0.18*** (0.04)
awareness	0.04 (0.04)	0.04 (0.04)	0.04 (0.04)	0.04 (0.04)	0.04 (0.04)	0.04 (0.04)
risk attitude	0.02 (0.01)	0.01 (0.01)	0.01 (0.01)	0.02 (0.01)	0.02 (0.01)	0.01 (0.01)
seriousness of climate change	0.13*** (0.04)	0.13*** (0.04)	0.13*** (0.04)	0.18*** (0.05)	0.13*** (0.04)	0.13*** (0.04)
<i>Values</i>						
ecological	0.11** (0.04)	0.11** (0.04)	0.11** (0.04)	0.11** (0.04)	0.11** (0.04)	0.11** (0.04)
altruistic	-0.02 (0.03)	-0.02 (0.03)	-0.02 (0.03)	-0.02 (0.03)	0.01 (0.04)	-0.02 (0.03)
egoistic	0.09*** (0.03)	0.09*** (0.03)	0.09*** (0.03)	0.09*** (0.03)	0.09*** (0.03)	0.07 (0.04)
security	0.07** (0.03)	0.06 (0.03)	0.07** (0.03)	0.07** (0.03)	0.07** (0.03)	0.07** (0.03)
<i>Attitudes</i>						
is easy way out	-0.11*** (0.03)	-0.11*** (0.03)	-0.11*** (0.03)	-0.11*** (0.03)	-0.11*** (0.03)	-0.11*** (0.03)
not manipulate this way	-0.26*** (0.03)	-0.25*** (0.03)	-0.25*** (0.03)	-0.26*** (0.03)	-0.25*** (0.03)	-0.25*** (0.03)
<i>Other Factors</i>						
trust	0.24*** (0.04)	0.24*** (0.04)	0.24*** (0.04)	0.24*** (0.04)	0.24*** (0.04)	0.24*** (0.04)
cognitive reflection	-0.04* (0.02)	-0.05** (0.02)	-0.04* (0.02)	-0.04* (0.02)	-0.04* (0.02)	-0.04* (0.02)
<i>Socio-demographics</i>						
religiousness	0.05** (0.02)	0.05** (0.02)	0.05** (0.02)	0.05** (0.02)	0.05** (0.02)	0.05** (0.02)
female	-0.03 (0.05)	0.09 (0.06)	-0.03 (0.05)	-0.03 (0.05)	-0.03 (0.05)	-0.03 (0.05)
high education	-0.06 (0.05)	-0.05 (0.05)	-0.06 (0.05)	-0.06 (0.05)	-0.06 (0.05)	-0.06 (0.05)
age	0.00* (0.00)	0.00* (0.00)	0.00* (0.00)	0.00* (0.00)	0.00* (0.00)	0.00* (0.00)
region	-0.03 (0.06)	-0.03 (0.06)	-0.03 (0.06)	-0.04 (0.06)	-0.03 (0.06)	-0.04 (0.06)
<i>Interaction Terms</i>						
female * info		-0.25*** (0.08)				
risk attitude * info			0.01 (0.02)			
seriousness of climate change * info				-0.11 (0.07)		
altruistic * info					-0.06 (0.06)	
egoistic* info						0.04 (0.06)
constant	2.23*** (0.16)	2.17*** (0.17)	2.26*** (0.17)	2.11*** (0.19)	2.24*** (0.16)	2.23*** (0.16)
Observations	898	898	898	898	898	898
Adjusted R <sup>2</sup>	0.3202	0.3260	0.3196	0.3221	0.3202	0.3199

Standard errors in parentheses. \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ .

Table A-5: OLS regression of afforestation acceptance. Note: Acceptance is measured on a scale of 0 (strongly disagree) to 3 (strongly agree). All other variables are also measured on scales of 0 to 3. Exceptions are dummy variables (info, awareness, female, high education, region), risk attitude (scale is from 0 to 10), and age.

Variables for values and trust are standardised indices.

## **1) Information provided in the SRM video**

### **Information provided in both the basic and the full information video**

Sunlight warms the Earth and its atmosphere. Greenhouse gases in the atmosphere such as CO<sub>2</sub> ensure that some warmth remains close to the Earth's surface. This makes the Earth warm enough for humans, animals, and plants to live on.

Since the start of industrialisation around 1850, people have emitted a great amount of greenhouse gases by burning coal, oil, and gas. These gases trap more heat in the atmosphere and cause a gradual increase in the average global temperature.

Since 1900, the global temperature has risen by approximately 0.8°C. Almost all countries agree that the increase in the average global temperature should not exceed 2°C compared to pre-industrial levels. This is called the 2°C target.

By 2100, a further increase in temperature between 0.9 and 5.4°C is expected. The development depends strongly on the amount of greenhouse gases emitted in the future. To reach the 2°C target, the current level of emissions would have to be cut by more than half by 2050. By 2100, greenhouse gas emissions would have to be reduced to almost zero.

It is virtually certain that climate change will cause a rise in sea levels. The frequency of heat waves is very likely to increase as well as the number of heavy precipitation events in many regions. It is likely that, in the future, more areas will be affected by extensive droughts and that the frequency and intensity of tropical cyclones will increase. In addition, part of the emitted CO<sub>2</sub> is absorbed by the ocean, causing ocean acidification.

There are different ways of dealing with climate change.

We can reduce greenhouse gas emissions or adapt to the new climate by building dikes. Another option is to reduce global temperature by deploying solar radiation management (SRM).

Via SRM some sunlight is reflected before it can warm the Earth. One way of doing this is by spraying sulphate particles into the atmosphere at a high altitude.

A similar phenomenon can be observed in nature. When large volcanoes erupt, similar particles are distributed across wide areas of the Earth's atmosphere, cooling the Earth.

The particles remain in the higher regions of the atmosphere for approximately two years. To prevent the Earth from heating up again, spraying would have to go on until the cause of global warming has been removed. Because CO<sub>2</sub> remains in the atmosphere for a very long time, SRM might have to be used for several centuries. However, using SRM will not stop ocean acidification.

### **Additional information provided in the full information video**

Currently, research is being done on the risks, the benefits, and the feasibility of SRM.

The use of SRM entails benefits as well as risks. One of the benefits is that global warming could be slowed more quickly than by reducing greenhouse gas emissions. This would buy additional time to remove the cause of climate change, i.e., the high concentration of greenhouse gases in the atmosphere. Massive and irreversible changes in the climate could be stopped before too much damage has been done. Also, it would be possible to stop climate change even if certain countries did not want to reduce their greenhouse gas emissions. Deploying SRM would be less expensive than reducing the consumption of fossil fuels.

The risks include a change in the amount of precipitation in most regions. Arid regions in particular would have to cope with even less rain. If the deployment of SRM was suddenly stopped, the global temperature would rise abruptly. The speed of this rise in temperature would lead to severe problems for humans and the environment. Because possible side-effects would be trans-boundary, the use of SRM could cause international conflicts. Once used, SRM could take away people's motivation to change their lifestyle, and greenhouse gas emissions would continue to increase. There would also be the possibility of further unknown and unforeseeable risks arising.



## **2) Information provided in the CCS video**

### **Information provided both in the basic and the full information video**

Sunlight warms the Earth and its atmosphere. Greenhouse gases in the atmosphere such as CO<sub>2</sub> ensure that some warmth remains close to the Earth's surface. This makes the Earth warm enough for humans, animals, and plants to live on.

Since the start of industrialisation around 1850, people have emitted a great amount of greenhouse gases by burning coal, oil, and gas. These gases trap more heat in the atmosphere and cause a gradual increase in the average global temperature.

Since 1900, the global temperature has risen by approximately 0.8°C. Almost all countries agree that the increase in the average global temperature should not exceed 2°C compared to pre-industrial levels. This is called the 2°C target.

By 2100, a further increase in temperature between 0.9 and 5.4°C is expected. The development depends strongly on the amount of greenhouse gases emitted in the future. To reach the 2°C target, the current level of emissions would have to be cut by more than half by 2050. By 2100, greenhouse gas emissions would have to be reduced to almost zero.

It is virtually certain that climate change will cause a rise in sea levels. The frequency of heat waves is very likely to increase as well as the number of heavy precipitation events in many regions. It is likely that, in the future, more areas will be affected by extensive droughts and that the frequency and intensity of tropical cyclones will increase. In addition, part of the emitted CO<sub>2</sub> is absorbed by the ocean, causing ocean acidification.

There are different ways of dealing with climate change.

We can reduce greenhouse gas emissions or adapt to the new climate by building dikes. Another option is carbon capture and storage sub-seabed (CCS).

The CCS technology captures CO<sub>2</sub> from the industrial combustion of fossil fuels. The CO<sub>2</sub> is compressed and stored in suitable geological formations under the seabed. It is not released into the atmosphere. This process additionally uses approximately 25% of the energy generated, which increases the overall demand for fossil fuels.

On a small scale, CO<sub>2</sub> has already been stored in the ground for approximately 30 years. For the recovery of oil and gas, CO<sub>2</sub> is injected to facilitate this process. Experience with this method indicates a high level of storage safety.

Former oil and gas fields as well as sub-seabed saline aquifers are considered to be safe and permanently suitable deposits. Pipelines and ships carry the compressed CO<sub>2</sub> to the deposits. Then it

is pumped into tiny hollows of the sub-seabed deposit, where it has to be stored for several thousands of years. During this time it merges with the rock, rendering it permanently harmless.

**Additional information provided in the full information video**

Scientists think that further applied research on CCS would be useful. The processes, benefits, and risks are already well understood.

In the following you will learn more about some of the expected benefits and risks of CCS.

Two of the benefits of CCS are that both global warming and the acidification of the oceans would be slowed down. Furthermore, deploying CCS would be less expensive than an energy transition from fossil fuels to renewable energies.

One of the risks of CCS is that increased pressure might cause leakage of CO<sub>2</sub> from the well or from the deposits. This could lead to local acidification, which would endanger the biodiversity of the area in question.

### **3) Information provided in the afforestation video**

#### **Information provided both in the basic and the full information video**

Sunlight warms the Earth and its atmosphere. Greenhouse gases in the atmosphere such as CO<sub>2</sub> ensure that some warmth remains close to the Earth's surface. This makes the Earth warm enough for humans, animals, and plants to live on.

Since the start of industrialisation around 1850, people have emitted a great amount of greenhouse gases by burning coal, oil, and gas. These gases trap more heat in the atmosphere and cause a gradual increase in the average global temperature.

Since 1900, the global temperature has risen by approximately 0.8°C. Almost all countries agree that the increase in the average global temperature should not exceed 2°C compared to pre-industrial levels. This is called the 2°C target.

By 2100, a further increase in temperature between 0.9 and 5.4°C is expected. The exact development depends strongly on the amount of greenhouse gases emitted in the future. To reach the 2°C target, the current level of emissions would have to be cut by more than half by 2050. By 2100, greenhouse gas emissions would have to be reduced to almost zero.

It is virtually certain that climate change will cause a rise in sea levels. The frequency of heat waves is very likely to increase as well as the number of heavy precipitation events in many regions. It is likely that, in the future, more areas will be affected by extensive droughts and that the frequency and intensity of tropical cyclones will increase. In addition, part of the emitted CO<sub>2</sub> is absorbed by the ocean, causing ocean acidification.

There are different ways of dealing with climate change.

We can reduce greenhouse gas emissions or adapt to the new climate by building dikes. Another option is large-scale afforestation.

As they grow, trees gradually absorb CO<sub>2</sub> from the atmosphere and store it in the wood. By logging mature trees and replacing them with new ones, CO<sub>2</sub> can be continuously absorbed from the atmosphere. To prevent the CO<sub>2</sub> from re-entering the atmosphere, the logged trees can be used as building material or simply buried.

To slow down climate change through afforestation, very large areas would have to be covered with trees. Especially suitable areas are the tropics, the Sahara Desert, and the Australian Outback.

**Additional information provided in the full information video**

Scientists agree that enough research has been done on the local effects. Further research is needed on the long-term effects on natural cycles.

Here are some of the expected benefits and risks of large-scale afforestation.

Two of the benefits of large-scale afforestation are that both global warming and acidification of the ocean would be slowed down. In addition, the quality of soil and water would be improved.

The risks include high water consumption for afforestation, which could lead to regional water scarcity. For afforestation agricultural areas would also have to be used. The afforestation of these areas could lead to food scarcity and thus increase food prices.

Also, large-scale afforestation would take longer to slow down climate change than the mitigation of greenhouse gas emissions.